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Forest Experiment
Station

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U. S. DEPARTMENT OF AGRICULTURE
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Lake States Forest Experiment Station[1]

Station Paper No. 30 January 1954

TESTS OF A PORTABLE WOOD CHIPPER[2] IN UTILIZING LOGGING RESIDUE AND IN DISPOSING OF BRUSH

By

J. L. Arend, R. N. Smith, and R. A. Ralston[3] [4]

INTRODUCTION

Portable wood chippers offer possibilities for closer utilization of our existing timber supply. At present a large part of the volume of each tree cut in timber stand improvement and commercial logging operations is left unused in the woods because of the high cost of converting rough wood of small size and irregular shape into usable products. Conversion of such material to chip form for bulk handling in the woods may be one way to reduce these costs.

On many brush disposal operations portable wood chippers have already proved to be money-saving tools. Tree trimmings sometimes may be disposed of in the form of chips along the right of way. If this method of disposal is undesirable, the chips may be blown into a truck and hauled away at less cost than that of hauling bulky brush or branches.

Portable wood chippers also produce chip material which is useful in agriculture. Wood chips produced with portable machines have been used successfully as a mulch for orchard trees and other horticultural crops (6), as bedding for livestock (2), and chicken litter (6). On or near most farms there is a supply of wood that can be chipped to meet these agricultural needs.

1/ Maintained at St. Paul 1, Minnesota, by the U. S. Department of Agriculture in cooperation with the University of Minnesota.

2/ Furnished by Mitts & Merrill, Inc., Saginaw, Michigan, with whose cooperation the study was made.

3/ Research Foresters, Lake States Forest Experiment Station, Lower Peninsula Forest Research Center. This Center is maintained in cooperation with Michigan State College at East Lansing, Michigan.

4/ Special acknowledgment is made of the assistance provided by E. W. Fobes and others at the Forest Products Laboratory, Madison, Wisconsin.

The practical use of a portable wood chipper for the disposal of slash, brush, and other wood material depends primarily on its ability to reduce costs over other methods of disposal, such as piling and burning or hauling the material to dumping grounds. Where the object is the production of merchantable chips from currently unused wood material, the practical use of the chipper depends mainly on the quality of the chips, availability of markets, and the margin of profit between the costs of chip production and value. Properly controlled, close utilization is allied with good conservation practices. Foresters, therefore, are interested in the use that can be made of portable wood chippers as a tool in forest management and production.

PURPOSE OF STUDY

In view of the potential uses for portable wood chippers in forestry and allied fields, a series of performance tests was made in Lower Michigan during 1953 to obtain data for one type of chipper operating under typical field conditions. Some of the trials included production tests to investigate the practicability of chipping and utilizing the portions of aspen and pine trees that are generally left in the woods as residue after a pulpwood logging operation. Tests were also made in which brush and slash from plantation thinning and pruning operations, orchard prunings, and tree trimmings from along right-of-ways were chipped.

A description of the portable wood chipper used in the study, the types of wood material chipped, average wood chip production rates and costs obtained, characteristics of the chips produced, and general performance of the machine tested are presented and discussed in this report.

DESCRIPTION OF THE PORTABLE WOOD CHIPPER USED

The wood chipper used in these tests was designed primarily to chip brush, branches, and tree tops up to 6 inches in diameter. One basic model was tested with and without several modifications made to increase chip production (see detailed description).

The complete machine consists of a two-wheeled, rubber-tired, trailer upon which are mounted the power and chipper units (fig. 1). Power is transmitted from a 4-cylinder, V-type air-cooled engine through a clutch and V-belt drive to the cylindrical chipper. The wood is cut into small chips by eight cutting knives (12 on the modified model) mounted on the base of the cylinder and three stationary cutting bars (two on modified model), spaced several inches apart under the cylinder. Air currents, initiated by vanes mounted on the side of the cylinder, carry the chips up and out of a discharge pipe.

The top portion of the discharge pipe is curved so that the end of the pipe is about 9 feet above the ground almost directly over the trailer hitch. This height may be increased by the insertion of short sections in the middle of the pipe. The elevation and forward angle of the discharge pipe allows the use of a truck with a high-sided box so that a large volume of chips may be carried in each load.

The end of the discharge pipe may be turned 90 degrees in either direction, thus permitting either side loading the chips or blowing them directly on the ground. An adjustable deflector at the mouth of the discharge pipe controls the angle of discharge. Chips may thus be blown anywhere between 5 to 50 feet from the chipper.

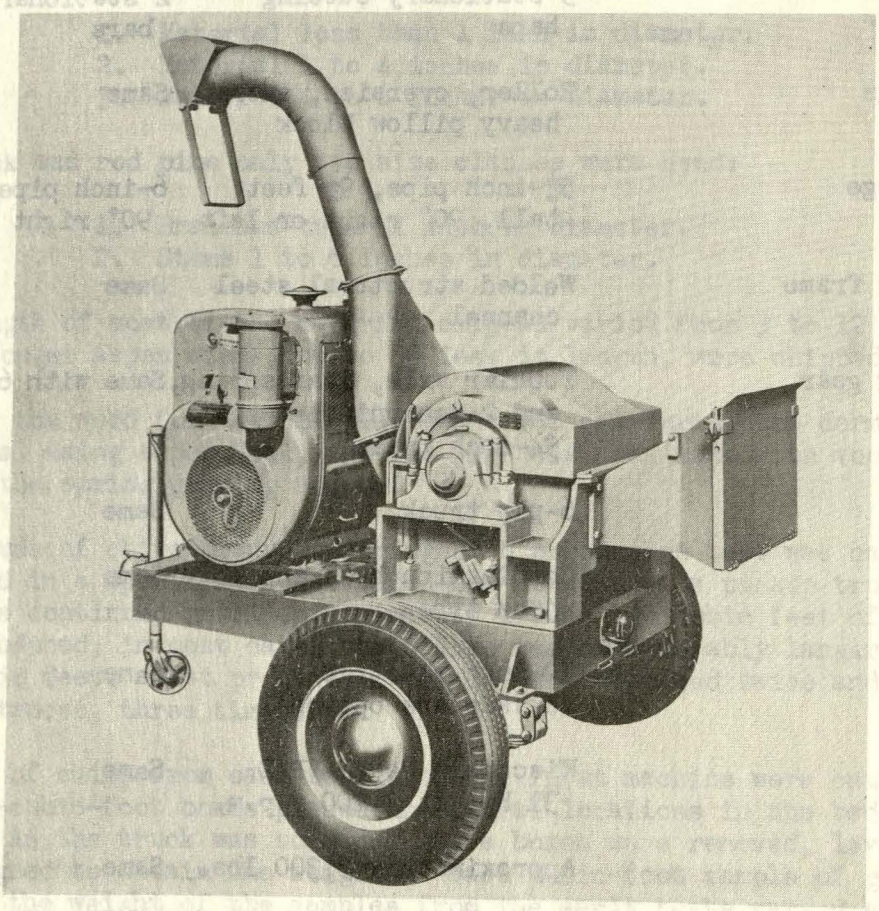


Figure 1.—Portable wood chipper unit tested during this study.

Detailed specifications of both models of the portable chipper tested follow:

Item	Original Machine	Modified Machine
Chipper frame	Welded steel plate	Same
Cylinder	20 inches in diameter, 1,500 r.p.m.	20 inches in diameter, 2,200 r.p.m.
Center line of cylinder to bed plate	8 inches	9½ inches
Knives	8 revolving knives, 3 stationary cutting bars	12 revolving knives, 2 stationary cutting bars
Bearings	Roller, oversize, extra heavy pillow block	Same
Discharge	5½-inch pipe, 9½ feet tall, 90° right or left	6-inch pipe, 8-feet tall, 90° right or left
Trailer frame	Welded structural steel channel	Same
Running gear	Tubular axle, leaf spring, and 2 demountable wheels, 54-inch tread	Same with 60-inch tread
Tires	6-ply truck	Same
Coupler	Combination ball and jack type	Same
Brakes	12-inch electric brakes are optional	Same
Engine	Wisconsin Model VP4D 31 hp. at 2,200 r.p.m.	Same
Weight	Approximately 3,300 lbs.	Same
Fuel tank capacity	9 gallons	Same

DESCRIPTION OF PERFORMANCE TESTS

Performance tests were conducted in connection with logging and brush disposal operations at several different locations in Lower Michigan. Tests with the original model of the chipper, using red and white oak, were made near Maple Rapids, Clinton County, during December 1952 and January 1953. Tests with aspen and jack pine were carried out on the Lower Michigan National Forest in Wexford County during January and March of 1953. One performance test was made in which apple orchard trimmings were chipped in late March 1953 in Mason County. Supplemental performance tests with the modified model, in which oak, aspen, and red pine were chipped, were also carried out during June 1953 to compare performance records with the earlier model machine tested.

The wood material for the oak and aspen tests was sorted into the following diameter classes, measured at the large end:

1. Material less than 1 inch in diameter.
2. Material 1 to 4 inches in diameter.
3. Material 4 to 6 inches in diameter.

For jack and red pine only two size classes were used:

1. Branches under 1 inch in diameter.
2. Stems 1 to 6 inches in diameter.

The length of most of the material chipped varied from 3 to 12 feet. A few longer aspen stems, up to 30 feet in length, were chipped.

Most of the wood for the chipping tests was cut during the dormant season. One trial using aspen, oak, and red pine also was made with wood cut during the spring growing season.

The volume of chips produced during each production test was caught and measured in a specially constructed box mounted on a pickup truck. Each test was continued until approximately 100 to 150 cubic feet of chips were produced; in most cases the volume was considerably larger than 100 cubic feet. Most production trials were repeated twice and, in a few instances, three times.

Samples of chips from each test with the first machine were caught in three 1-cubic-foot boxes placed in several locations in the bed of the truck. As the truck was unloaded these boxes were removed, leveled, and weighed to obtain the weight of each cubic-foot sample of green chips. Because the weight of the samples from the early tests varied somewhat with position in the load, wood chip samples taken during the supplemental tests with the modified machine were scooped from the load as the truck was being emptied. Each of these cubic-foot samples was shaken and leveled until settling was no longer apparent and then weighed to obtain the weight of the green chips. Later the oven-dry weights of the samples were determined.

Other information collected during the performance tests included:

1. The average time required to move the chipper from one pile of brush to another on the same operation.

2. The approximate ratio of solid wood to wood chip volume.

3. The approximate ratio of piled brush to wood chip volume.

4. An estimate of the average volume of wood available in the tops of aspen and jack pine left in the woods as residue after a pulpwood logging operation.

5. The amount of settling of chips in the truck box after 1 to 4 miles of driving.

RESULTS

Production Rates

Production rates varied considerably according to the species and diameter class of wood chipped, and the model of machine used (tables 1 and 2). Production rates are presented in cubic feet of chips per hour (tables 1 and 2) rather than in tons or pounds per hour because the weight of chips per unit volume for a given species and size class of material can be quite variable, depending mainly on the moisture content of the unchipped wood.

These production rates are based on total chipping time, including operational delays, with two men feeding the machine from piles of wood previously prepared. Even though the material to be chipped was prepared and piled for each test, there were numerous short periods when the machine was running empty. Consequently, the production rates presented are not the maximum for the size class of material being chipped by this particular type machine. However, the production rates obtained are quite representative of operations where a supply of piled wood is available.

Table 1.--Volume[1] in cubic feet of wood chips produced per hour[2] with chipper having eight knives by species.

Species	When diameter class is:[3]			
	0-1 inches	1-4 inches	4-6 inches	Average, 0-6 inches
Oak	77	137	169	128
Aspen	83	216	241	180
Jack pine	[4]232	[5]183	---	---

1/ Settled volume of chips after load had been transported 1 to 4 miles.

2/ Production rates are based on chipping time from the start to the end of each test with two men feeding the machine. All operational delays that occurred while feeding the machine with prepared wood are included.

3/ Random lengths varying generally from about 3 to 12 feet.

4/ Jack pine limbs of this diameter class include the foliage, which increased the production per hour considerably compared to hardwood branches of similar size with no foliage.

5/ Diameter class was actually 1 to 6 inches with no foliage attached.

Table 2.—Volume[1] in cubic feet of wood chips produced per hour[2] with chipper having 12 knives by species.

Species	When diameter class is:[3]			
	0–1 inches	1–4 inches	4–6 inches	Average, 0–6 inches
Oak	[4]286	170	128	195
Aspen	141	227	197	188
Red pine	[4]269	239	—	254

1/ Settled volume of chips after load had been transported 1 to 4 miles.

2/ Production rates are based on chipping time from the start to the end of each test with two men feeding the machine. All operational delays that occurred while feeding the machine with prepared wood, including delays due to unavoidable stalling, are included.

3/ Random lengths varying from 3 to 12 feet.

4/ Freshly cut branches with attached foliage still green.

Eight-Knife Machine

With the original model, wood chip production in cubic feet per hour increased with the diameter class of the material chipped for all species used in the tests, except for freshly cut jack pine limbs with foliage (table 1). The largest increase in chip production rate, however, occurred when this machine was used to chip material 1 to 4 inches in diameter as opposed to material generally less than 1 inch in diameter. Several reasons can be advanced to explain this increase in wood chip production rates when the larger size class of material was chipped. There is more solid wood in larger sticks of wood than there is in an armload of brush. Consequently, the chipper received a larger volume of solid wood per revolution of the cylinder when larger sticks were fed than when small brush was used. When feeding brush (wood material generally less than 1 inch in diameter), there was also more delay while the machine was running empty between loads than when larger material was being chipped. In these tests the brush material was mainly short (under 6 feet in length) and crooked. If longer and straighter material had been used, perhaps the production rate for this size class would have been higher.

Twelve-Knife Machine

Wood chip production rates with the modified model of the chipper were higher for material up to 4 inches in diameter and less for material exceeding this diameter than those with the original machine (table 2). For oak, production rates decreased as the diameter of rough wood chipped increased. Opposite results were obtained with aspen. The increase in volume of wood chips produced per hour by the newer machine with small brush resulted primarily from improved mechanical features, although straightness of some of the wood material chipped and the presence or absence of foliage were added factors.

The changes in mechanical features of the chipping machine, which were mainly responsible for increased wood chip production from small material, included an increase in the number of cutting knives from 8 to 12, an increase in cylinder speed from 1,500 to 2,200 r.p.m., a larger feeding hopper, and a lower feed bed. Enlargement of the feeding hopper permitted larger armfuls of brush to be fed into the machine. Lowering the feed bed increased the cutting angle, thereby causing all sizes of wood material to be pulled into the chipper faster than with the original model. All of these changes resulted in an increase in production of wood chips from material up to about 4 inches in diameter. However, when chipping wood material over 4 inches in diameter, these modifications in design resulted in decreased rates of chip production. The 12-knife machine was easily stalled by sticks of wood 4 inches in diameter and larger. Wood of this size had to be fed very slowly to prevent stalling. In fact, the operator had to hold back on each stick with considerable force to prevent stalling, because the newer model machine was capable of pulling sticks as large as 6 inches in diameter (as large as were tested) into the knives under its own power.

Straightness of Material Chipped

Straightness of the wood material chipped affects production rates as demonstrated by the results obtained from aspen and oak brush (tables 1 and 2). The hourly rate of chip production for straight lengths of oak brush with the newer model machine was nearly four times that obtained with the older one, whereas production was not even doubled with crooked aspen brush used in both tests. Everything else being equal, wood chip production with aspen should exceed that from oak wood because the resistance to cutting strength of oak is higher than that of aspen. However, the presence of foliage and straightness of the oak brush used in the second test undoubtedly contributed to the increased wood chip production rates in the latter case.

The wood material 1 inch and larger in diameter chipped during these tests with both models of the machine was quite similar in respect to straightness and length. However, these characteristics were variable for wood material up to 1 inch in diameter.

Oak material, up to 1 inch in diameter, chipped with the older model, was prepared mainly from tops cut during the dormant season. The sticks were generally 3 to 6 feet in length and very crooked. Production averaged 77 cubic feet of wood chips per hour from this type of wood material with the older machine (table 1). The oak material of the same diameter class chipped with the newer model machine was obtained from roadside brush. This material was approximately 5 to 12 feet in length and fairly straight. With the newer model machine production averaged 286 cubic feet of wood chips per hour for oak less than 1 inch in diameter.

Dryness of Wood Chipped

Dryness of the wood material chipped had little effect on production with the newer model machine. The same production rates were obtained from freshly cut oak brush as from similar oak brush cut 5 months prior to the time it was chipped.

Aspen brush from the same logging operation was used in the performance tests with both models of the machine. Consequently, the character of the wood material was very similar. However, wood chip production from aspen brush, up to 1 inch in diameter, was 83 cubic feet per hour with the older machine compared to 141 cubic feet per hour with the newer one. Average wood chip production with the newer model chipper for brush material less than 1 inch in diameter was nearly double that obtained with the older machine.

Effects of Green Foliage

The amount of green foliage on the wood material chipped had a marked influence on production rates. Apparent production rates from pine branches with green foliage were higher with both models of the chipper than those obtained from larger size material of the same species without foliage. This increased production resulted mainly from fragments of needles and twigs which added to the volume and green weight. The oven-dry weight of a cubic foot of this chip material was relatively low (table 6).

All wood material chipped during these performance tests that was above 1 inch in diameter was free from foliage and relatively straight. Consequently the effects of foliage and straightness of the material chipped were not variables affecting production rates for chipped material over 1 inch in diameter.

Volume Ratio of Solid Wood to Wood Chips

A few tests were made to determine the volume ratio of solid wood to wood chips. The diameters of both ends and the lengths of sticks of oak, aspen, and jack pine were measured and the cubic volumes computed before they were chipped. The chips were collected and measured. The average volume of wood chips measured per cubic foot of solid wood ranged from around 2.3 cubic feet for jack pine and oak to 2.5 cubic feet for aspen. From these ratios it appears that about 200 cubic feet of wood chips can be obtained from a standard cord of wood with 80 cubic feet of solid wood.

Because of the inaccuracy of determining the solid contents of wood sticks from measurements of diameter and length, these ratios of the volume of solid wood to volume of wood chips are only approximate.

Volume Ratio of Piled Brush to Chips

Whole piles of oak and aspen brush, consisting of material less than 1 inch in diameter, were measured before they were chipped. It was found that 1 cubic foot of chips could be produced from 13 to 20 cubic feet of piled brush (table 3).

Table 3.--Volume of piled brush[1/] required to produce 1 cubic foot of chips

Species	Character of brush	Volume per cubic foot of chips
		Cubic feet
Oak	From tops of sawlog size trees	20
Oak	Saplings from right of way	15
Oak	Saplings from right of way	13
Aspen	From pulpwood tops	13
	Average	15

1/ Carefully piled and compacted by its own weight.

The ratio of piled brush to volume of wood chips can vary considerably depending principally on species, average diameter, crookedness, variability of lengths, proportion of whole tops, and degree of compactness. The average ratio, 15:1, was obtained from neatly piled oak brush that was compacted only by its own weight (figs. 2a and 2b).

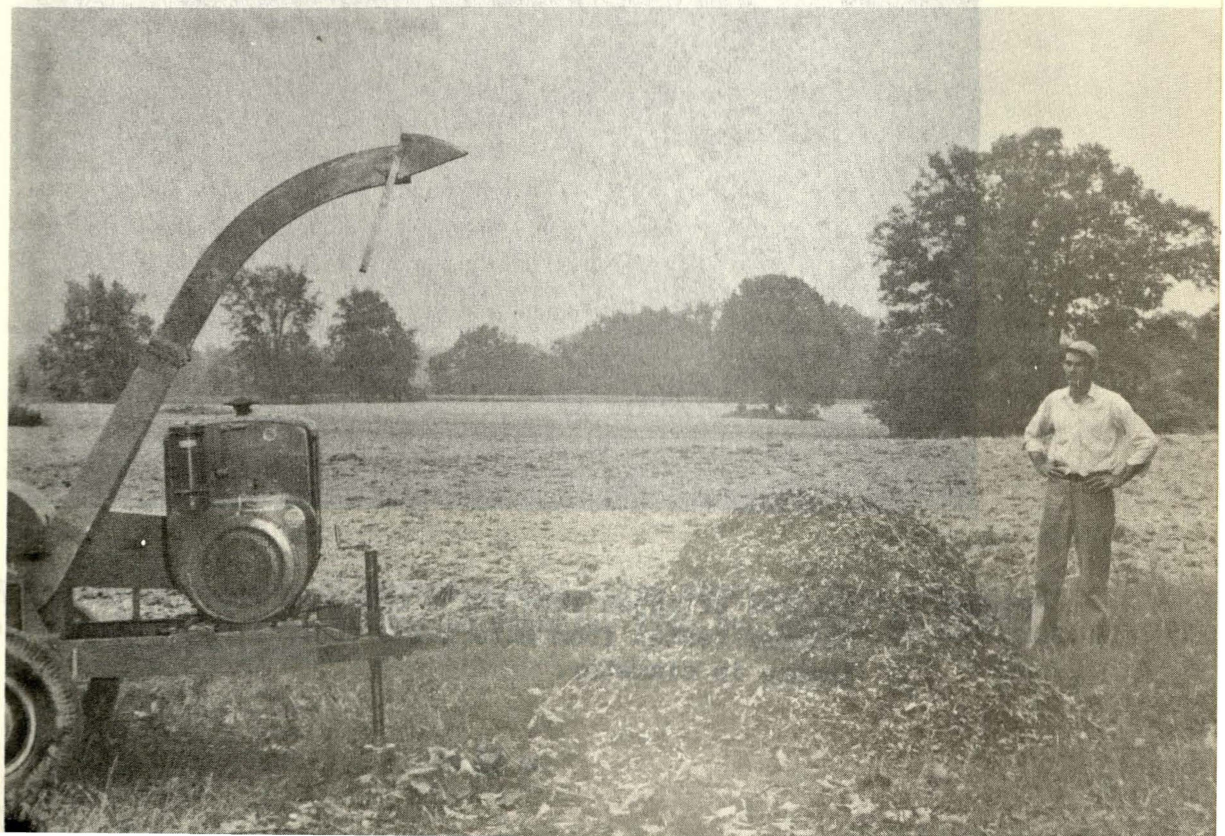
Character of Wood Chips Produced

Size and Texture

The size and texture of individual wood chips varied somewhat with the species and the diameter of the material chipped as well as with the model of the portable chipper used (figs. 3 and 4). The wood chips produced from material exceeding 1 inch in diameter with both models of the portable chipper tested were smaller than chips made by most large disc chippers used in pulp mills. Samples of oak and aspen chips produced from material 1 to 6 inches in diameter were sifted through screens of three different sizes--1 inch, 1/2 inch, and 1/4 inch mesh. The proportion of wood chips by these size classes differed for the two models of the chipper tested (table 4).

Figure 2a.--This pile of oak brush was chipped in 20 minutes.

Figure 2b.--The oak brush in fig. 2a was reduced to this amount of chips. It was found that an average of 15 cu. ft. of piled brush reduced to 1 cu. ft. of wood chips.



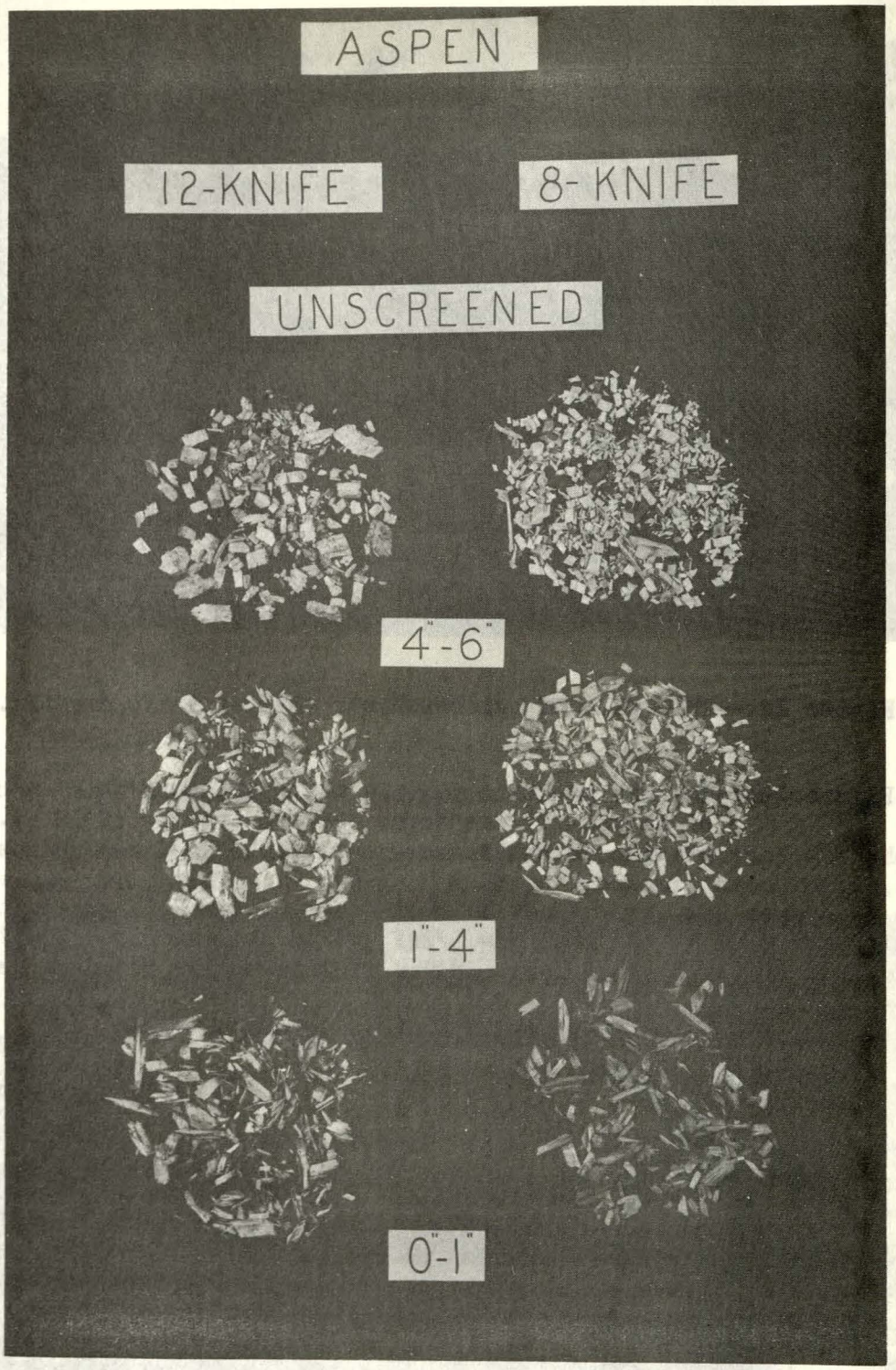


Figure 3.—Samples of aspen wood chips obtained with the portable chipper tested from material 0 to 1, 1 to 4, and 4 to 6 inches in diameter.

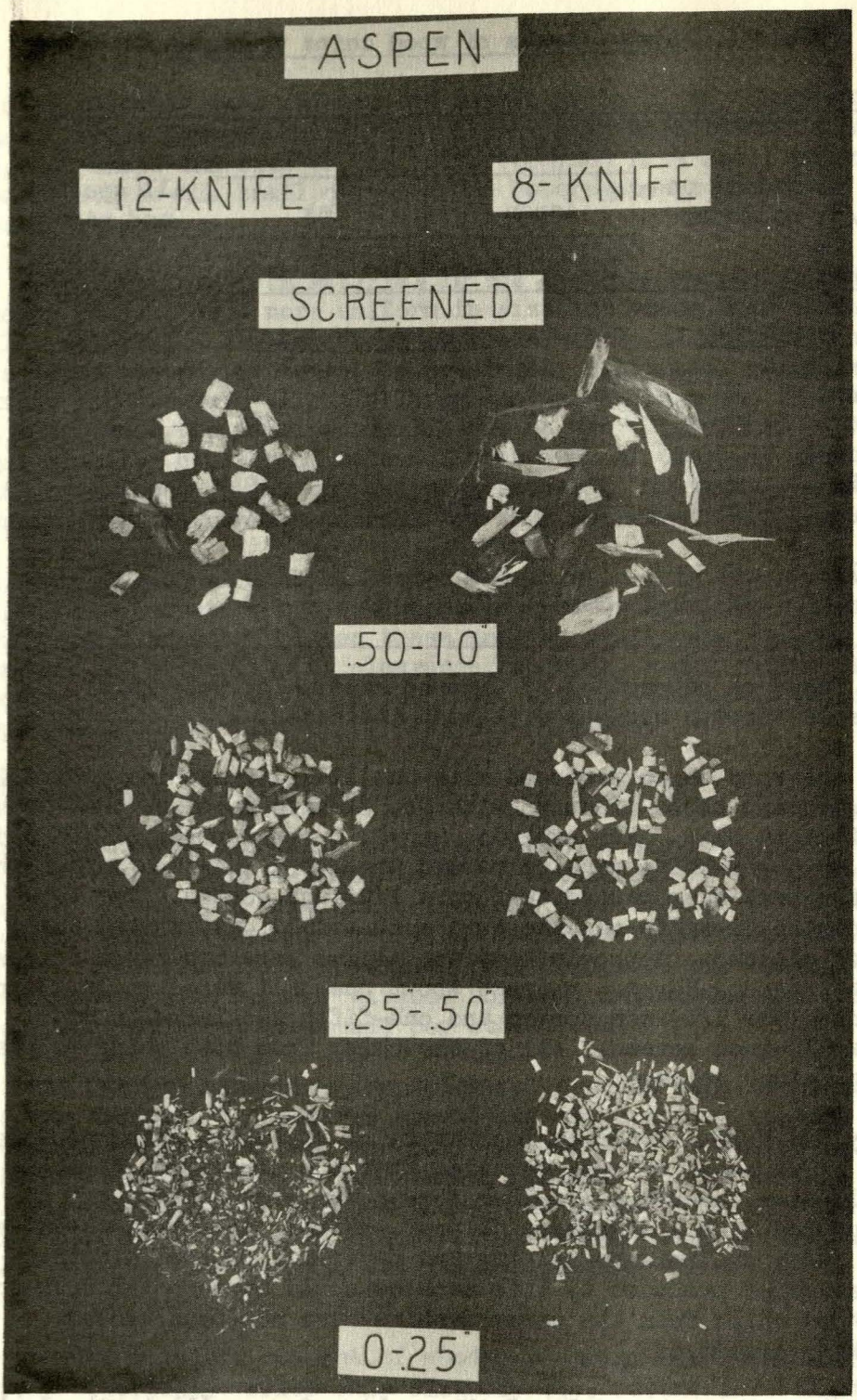


Figure 4.—Size classes of screened wood chips obtained from aspen sticks 1 to 4 inches in diameter with two models of the chipper tested.

Table 4.—Size classes of wood chips produced

Size of chips 1/ (inches)	Knives on cylinder	Chips produced from -				All species and sizes
		Aspen		Oak		
		1-4	4-6	1-4	4-6	
	Number	Percent of total				
0 - 1/4	8	65	71	65	82	71
	12	25	36	34	39	33
1/4 - 1/2	8	29	25	31	13	24
	12	44	42	50	44	45
1/2 - 1	8	6	4	4	5	5
	12	31	22	16	17	22

1/ Based on percentage of 2-pound samples of wood chips which passed through screens with mesh indicated.

Although the wood chips produced with the 12-knife machine generally were larger than those produced with the 8-knife machine, they were less uniform in size. For example, nearly three-fourths of the chips produced by the 8-knife machine passed through a 1/4-inch screen and most of the remainder passed through a 1/2-inch screen. The wood chips from the 12-knife machine were more evenly distributed among the three size classes. Approximately two-thirds were too large to pass through a 1/4-inch screen, whereas about one-half were too large to pass through the 1/4-inch screen and one-fifth too large to pass through a 1/2-inch screen. All of the chips from both chippers passed through a 1-inch screen.

A test by the Forest Products Laboratory of the aspen chips produced with the older model chipper revealed that the percentage of chips that would pass through a 1/4-inch screen was higher than that of chips produced with a disc-type chipper. Fiber length was satisfactory, however, and a preliminary pulping and paper-making test disclosed that aspen chips produced by this machine could be used for pulp and paper. Wood chips from the newer machine have not been tested for paper-making qualities.

Chips produced by both models of the machine from small brush, less than 1 inch in diameter, were higher in bark content than those from wood material exceeding 1 inch in diameter. This was true for all species tested because the ratio of bark to wood was higher in small material than it was in larger diameter wood. Brush and small limbs tended to

splinter somewhat when chipped and occasionally 3- to 4-inch long sections of twigs passed through the chipper with bark intact. The irregular shape and size of the chips obtained from small brush was probably due to the small diameter and heterogeneous character of the material chipped.

Wood chips obtained from material in the 1- to 4- and 4- to 6-inch diameter classes were more uniform in size and shape than those from smaller material. This was true for both models of the chipper and all species tested, although, as previously mentioned, chips from the 12-knife machine were slightly larger on the average and less uniform than those from the 8-knife one. Also, it was observed with the two larger diameter classes of material that much of the bark was broken off from the wood during the chipping process. No study was made to determine what percentage of bark was thus separated from the wood chips.

With either model of machine tested the size of chip may be varied by changing the amount of projection of the knives from the cylinder and varying the clearance between these and the stationary knives. Reducing the amount of projection or clearance, or both, would reduce the size of the chips. In this way it is possible, within limits, to adjust the chipper to produce chips of varying size classes.

Weight of Chips

Field Weight.--The weight of green oak chips averaged about 22 to 24 pounds per cubic foot compared to 17 to 21 pounds for aspen (tables 5 and 6). Green jack pine chips from the main stem of trees cut during the dormant season averaged nearly 30 pounds per cubic foot while chips from the limbs with foliage weighed only 18 pounds per cubic foot. Chips from red pine with or without foliage, cut during the growing season, weighed about 21 pounds per cubic foot.

Important factors affecting the weight of a cubic foot of green wood chips, in addition to specific gravity of the species, include moisture content, percentage of bark and foliage, and size of the chip. Studies by the Northeastern Forest Experiement Station (4) showed that knife setting, which affected the texture of the chips, also affected the weight of a given volume of green chips. Knife settings were not changed in this study so no data are available regarding the effect of this factor on wood chip volume and weight.

Although the moisture content of wood cut during different seasons of the year reportedly varies only slightly (8), recent investigations in northern Minnesota showed that the moisture content of aspen was considerably higher in the fall and winter than in the spring and summer (5). Therefore, the season of the year during which the wood is cut and chipped may have some effect on the weight of the chips produced from this species.

Table 5.—Weight and moisture content of wood chips produced during dormant season with 8-knife machine, by species and diameter classes

Diameter class (inches)	Weight per cubic foot		Moisture content 1/
	Green	Oven-dry	
	Lbs.	Lbs.	Percent
OAK			
0-1	23.2	14.1	65
1-4	22.6	14.2	59
4-6	26.8	15.6	72
Average	24.2	14.6	65
ASPEN			
0-1	23.9	13.0	84
1-4	19.8	9.7	104
4-6	19.5	9.4	107
Average	21.1	10.7	98
JACK PINE			
0-1	18.2	8.4	117
1-6	29.8	10.7	179
Average	24.0	9.5	148

1/ Based on oven-dry weight.

Table 6.—Weight and moisture content of wood chips produced during growing season with 12-knife machine, by species and diameter classes

Diameter class (inches)	Weight per cubic foot: Green	Weight per cubic foot: Oven-dry	Moisture content[1]
	Lbs.	Lbs.	Percent
OAK			
0-1[2]	(16.8)	13.5	(24)
0-1[3]	(16.6)	(9.6)	(73)
1-4	23.3	15.0	55
4-6	24.7	14.8	67
Average	24.0	14.4	61
ASPEN			
0-1[4]	16.1	10.9	48
1-4[4]	17.1	10.4	64
4-6	19.3	10.4	86
Average	17.5	10.6	66
RED PINE			
0-1	20.6	10.6	94
1-4	21.0	8.8	139
Average	20.8	9.7	116
APPLE			
0-1	22.2	12.5	78

1/ Based on oven-dry weight.

2/ Oak brush that was air-dried from February to June before chipping. Moisture content of this material therefore is not comparable with that of other samples and was not used to obtain average moisture content.

3/ Oak brush, freshly cut. This was the only test with hardwood material containing green foliage. Bracketed figures were not used in the averages for oak. Because of the presence of foliage, green and oven-dry weights were far less than normal and were not used to obtain averages of these weights for oak.

4/ Cut during December; air-dried until June before chipping.

The moisture content of the chips obtained from the wood material chipped varied considerably (tables 5 and 6). These differences in moisture content were due primarily to the degree of seasoning of the wood before it was chipped, with the exception of oak brush chipped with the 12-knife machine. In the latter case the high proportion of green foliage influenced both the green and dry weights of the chips produced.

The moisture content of brush and slash may vary considerably, depending upon season and length of time since cutting. Wood from the lower part of the tree usually contains more moisture than that from the upper portion (8). Wood material cut during the dormant season usually dries more slowly than similar material cut during the growing season. The faster drying rate of material cut during the growing season results from more favorable temperature and humidity conditions at this time of year. Transpirational loss because of the presence of green foliage also speeds up drying.

Oven-Dry Weight

The oven-dry weights of the wood chip samples averaged approximately 15 pounds per cubic foot for oak, about 11 pounds per cubic foot for aspen, and about 10 pounds for pine (tables 5 and 6). The differences in oven-dry weights of wood chips obtained from wood material of various diameter classes of the same species resulted chiefly from the relative proportions of bark and foliage. For example, the specific gravity of aspen bark is higher than that of aspen wood, while the bark of some species weighs less than the wood.5/ Because the weight of the chips is based on an average of only three 1-cubic-foot samples taken from each load of chips, possible variations within the load also may be expected to cause minor differences in the weights presented (tables 5 and 6).

From these tests it appears that the weight of green chips was not only variable but important. The weight of a volume of chips from freshly cut wood material was roughly twice its oven-dry weight. It took only 100 cubic feet of chips produced from green wood to make a ton. The boxes of most trucks can be modified to hold a volume of chips whose weight will greatly exceed the rated capacity of the truck. From the standpoint of reducing hauling costs and retarding deterioration of the wood chips in storage, the wood material should be air-dried to some extent before being chipped. However, resistance to chipping of wood generally increases as it dries. Therefore, the extent of air drying needs to be balanced with the cutting power of the chipper. The newer model machine chipped air-dry brush as fast as green material of the same size, but dry sticks over 3 to 4 inches in diameter were more difficult to chip than green wood of comparable size.

5/ Information obtained from correspondence with the Forest Products Laboratory.

Settling of the Chips

At the end of each production test the volume of chips collected was measured. The truckload of chips was then driven 1 to 4 miles and the volume of chips was remeasured to determine the amount of settling. The volume of chips after settling was used for production rates and weight. It was found that the chips settled between 2 and 4 percent in cubic volume for this amount of shaking.

Costs

Costs of owning and operating this chipper, like those of other types of equipment, are of two general types—fixed and operational.

Fixed costs are incurred by ownership regardless of the number of hours the machine is operated. They include cost of the machine, interest on the investment, and insurance. Although depreciation is a definite fixed cost, the period of depreciation depends somewhat on the type of owner. Where use is periodic, as in a farm operation, 10 years is a reasonable period over which the capital investment may be depreciated. However, if the machine is operated continuously, 5 years might be a more realistic period of depreciation. Another item affecting depreciation at the end of either a 5- or 10-year period will be the salvage or resale value of the chipper. Since most owners prefer to depreciate equipment as rapidly as possible, a 5-year period has been used to estimate fixed costs (table 7).

Operational costs include such items as gasoline, oil, sharpening of knives, and labor to operate the machine. These items are costs for each hour the machine is operated. Other expenses, such as replacement of knives, belts and miscellaneous repairs, also depend generally on how many hours the machine is operated. Consequently, these items have been listed as hourly operation costs (table 7). Of all the operational costs, labor is perhaps the most variable item. Prevailing labor rates vary locally. Therefore, local wage rates may be substituted for the $1.50 rate used in these calculations (table 7).

Another operational cost is the expense of towing the chipper. Since it may be towed by a number of vehicles having a ball hitch, such as a pickup, jeep, dump truck, or wheel tractor, all of which may be used for other purposes during the chipping operation, this expense item was omitted from operational costs.

Fixed Costs

The initial cost of the chipper at the present time is $2,700. Annual depreciation in a 10-year period amounts to $270; in a 5-year period $540. Assuming 1,000 working hours in a year, this amounts to $0.27 and $0.54 per hour for the 10- and 5-year depreciation periods, respectively. No estimate is made of the salvage or resale value of the chipper at the end of the depreciation period so the fixed costs are quite generous.

Operational Costs

Machine rates ranged from $0.99 to $1.02 per hour, depending on the number of knives. Gasoline consumption during the performance tests ranged from 2.2 to 3.3 gallons per hour. The average was 2.7 gallons per hour.

The knives need to be sharpened every 40 to 50 hours of operation. Of course, this depends to a considerable extent on the size of the material chipped and its cleanliness. It is estimated that the knives can be sharpened about 50 times before replacement is needed. Thus, the serviceable life of a knife is probably 2,000 to 2,500 operating hours.

Table 7.—Summary of fixed and operational costs

Cost item	Basis of calculations	Cost per hour
		Dollars
FIXED COSTS		
Depreciation	$2,700 over 5 years (5,000 hours)	0.54
OPERATIONAL COSTS		
Labor	2 men at $1.50 per hour 1/	3.00
Machine		
Gasoline	2.7 gallons at $0.25 per gallon	.675
Oil	5 qts. at $0.30, plus filter every 100 hours	.030
Lubrication	$0.50 every 50 hours	.010
Sharpen knives	$7.50 every 40 hours	2/ .188
Knife replacement	$100.00 every 2,000 hours	2/ .050
Belt replacement	$25.00 every 2,000 hours	2/ .012
Miscellaneous repairs	$50.00 every 2,000 hours	2/ .025
Sub-total	Machine operational costs	.99
Total	Fixed plus operational costs	4.53

1/ Substitute local wage rate.

2/ These cost estimates were furnished by the manufacturer of the chipper tested. Maintenance and replacement of knives in a 12-knife machine will cost about $0.03 more per hour than for an 8-knife model. Since most of the expense items in connection with knife maintenance are liberal, no cost was listed for the time required to change the knives.

GENERAL PERFORMANCE

Portability

The portable chipper used during these performance tests was well balanced and very mobile. It rode easily behind a pickup truck at highway speeds up to 55 miles per hour. Brakes are optional; however, the chipper used in these tests had no brakes so allowances had to be made for the added weight when stops were made. No difficulty was experienced in stopping or hauling the chipper safely during several hundred miles of driving over many types of roads.

In the woods the chipper was pulled wherever a 1/2-ton pickup truck would go. For roadside brush disposal purposes, where the chips are blown on the ground, the chipper may be towed by a jeep or pickup. Where the chips are to be caught and hauled away, a stake- or dump-truck may be used. Some difficulty was experienced in hauling the chipper over snow-covered roads, but chains and a partial load of chips as ballast helped make the most difficult roads passable. A farm tractor also pulled the chipper with ease on particularly muddy roads. Turns were no problem and backing, even for those inexperienced in the technique, was rather simple. Visibility around the chipper was good.

When it became necessary to move to another pile of wood while operating the chipper, one man simply got into the truck and drove. In many instances, particularly when chipping material exceeding 1 inch in diameter, one man continued to feed the machine as it was being towed to the next location, thereby reducing delay time. Otherwise there was usually about 1 minute of delay time for a move of 50 to 300 feet. When longer moves were made, and particularly when backing up was necessary, the chipper motor was turned off by the driver on his way forward and started again on his way back. Stopping required just an instant to turn off the key. Starting required about a minute delay to obtain sufficient chipping speed to continue the operation. After the chipping machine was started, it usually needed no further attention from the operator during the individual tests made.

Effects of Piling and Crew Organization on Production

No specific study was made of piling and crew organization during the performance tests. However, from experience gained and observations made during the tests, some of the following points were noted:

The most efficient crew size for general chipping work from prepiled brush appeared to be two men. When chipping small brush, material less than 1 inch in diameter, one man feeding the machine from material carried to him by the other was in many cases more efficient than having both men carry brush and feed the chipper. With the first system a small pile of brush was built up behind the chipper so that the operator could continue

to feed the machine if the man carrying brush was delayed. When each man made the trip from roadside brush piles to the chipper independently, there was likely to be more delay between loads because the men tended to get in each others way around the chipper. When the brush was piled along a road, a 3-man crew was too large. Each man in turn had to wait for the others. If brush were unpiled, however, a 3-man crew or larger would probably be more efficient than a 2-man crew. No observations were made of this arrangement when chipping brush.

When chipping wood material exceeding 1 inch in diameter from prepiled brush, both 2-man crew organizations were used with little difference in production rates. Each stick took time enough going through the chipper to allow one man to go to the roadside, pick up a stick, and return before the other man had left the machine. It appeared to work as well for one man to feed while the other carried, as for both men to feed and carry. There was also enough time for one man to level the load of chips occasionally. With 4- to 6-inch diameter material, one man could also move the truck to the next pile while the other man continued to feed the chipper.

All small material was piled before it was chipped, with the exception of one test. Although no attempt was made to test different methods of piling, it was found that careful piling of small brush was helpful. Very little extra time and effort were required to lay an armful of brush, or a stick, on a pile so that all pieces were approximately parallel. Any extra time thus spent in piling was more than regained when the material was removed from the piles.

Influence of Size and Type of Wood Material on Chipper Performance

The portable chipper tested was designed to chip wood material up to 6 inches in diameter and of any length easily handled by one or two men in brush disposal operations. In these performance tests the machine was found to have ample power to chip wood material, such as brush and limbs, with diameters seldom above 4 inches. When chipping small brush, production could usually be increased by feeding small armloads into the machine rather than full armloads. Large armloads frequently caused some delay in getting the brush started through the machine. When long, straight limbs and brush, less than 4 inches in diameter, were chipped, two or three pieces were fed at a time.

When wood material over 4 inches in diameter was chipped continually, the chipper was underpowered. Wood sticks 4 to 6 inches in diameter gradually slowed down the cylinder after 2 or 3 feet of length had been chipped. If sticks of this size exceeded 5 or 6 feet in length, the operator was forced to hold back several times on each stick for a few seconds to allow the cylinder of the newer model to accelerate again to chipping speed. If this procedure was not followed, the chipper slowed down until the engine stalled.

The portable wood chipper tested, especially the newer model, was well adapted for the disposal or utilization of small brush. Of course, this was the primary purpose for which the machine was designed. Wood material, once engaged with the cutting knives, was pulled into the chipper without further work on the part of the operator. Production rates with the 12-knife model varied from 141 cubic feet per hour for aspen brush 4 to 6 feet long to 286 cubic feet per hour for green oak brush less than 1 inch in diameter and about 12 feet long. The machine handled small dry brush about as efficiently as green material, although the resistance to chipping of wood increases as it dries. Dry brush was more difficult to handle, however, because of its unyielding nature but, once manually engaged with the cutting knives, it was pulled through the machine in about the same manner and about as fast as green material. When chipping brush, such as would be found on disposal operations, occasional large sticks up to 6 inches in diameter slowed down the machine, but they were chipped without much difficulty.

Safety

Both chippers used during these tests appear to be well designed for safe operation. Moving parts are covered. It is possible, however, for the operator's clothing to be snagged by the wood material as it is pulled into the machine. If moving brush should catch the operator's glove when he is off balance, there is a remote possibility that his hand could be drawn into the knives, since the knives can be reached from the feeding position.

The knives are well fastened in the revolving cylinder and, if properly installed, there is little possibility of a knife being thrown when the machine is running.

Safety goggles were worn during the performance tests. Goggles provide some protection against dust and whipping branches during the chipping operations and their use is recommended.

USES FOR PORTABLE WOOD CHIPPERS

Utilization of Logging Residue and Timber Stand Improvement

Pulp Chips

Pulp manufacturers prefer fairly uniform chips about five-eighths inch in length. Some want wood free of bark, leaves, and pitch. Some require segregation of softwoods, aspen, and other hardwoods. In general, these requirements rule out the employment of chips of the type produced with the chipper tested in this study. However, some pulp mills use rough jack pine and aspen and a few use rough mixed hardwoods and there may be a market for chips from the larger sticks, providing they are offered in reasonable volume and at an acceptable price.

The Forest Products Laboratory produced satisfactory paper from one experimental run of aspen chips from 1- to 4-inch wood salvaged from a logging operation with the portable chipper tested.

If an equivalent quantity of usable chips can be produced by portable chippers for a price substantially lower than standard pulpwood, it would seem that markets should be available at the pulp mills.

Because of the size limits of material that can be chipped, the use of this type of portable chipper at the present time would be restricted to the salvaging of pulp sticks 1 to 4 inches in diameter on pulpwood logging operations--assuming, of course, that the chips produced were acceptable for pulping purposes. On such operations the trees cut could be skidded in tree lengths to concentration points and bucked into standard length pulp sticks. Sticks, less than 4 inches in diameter, which are currently not acceptable, could be chipped with a portable machine (figs. 5a and 5b).

Under current cutting practices from 30 to 50 percent of the length of the stem often is not utilized. A considerable volume of wood may remain unused, therefore, especially in larger trees (table 8).

Figure 5a.--A considerable amount of logging residue is left in the woods on current pulpwood logging operations. Aspen bolts (lower left) are merchantable for pulpwood whereas small trees and sticks less than 4 inches in diameter (background), which can be utilized by a portable chipper, are left in the woods.

Figure 5b.--Aspen wood, unmerchantable by current utilization standards, being chipped from a pile of logging slash on a pulpwood operation in Lower Michigan.

Table 8.--Rough volume[1] in cubic feet of that portion of the main stem of aspen[2] remaining after cutting to various utilization standards[3]

D.b.h. (Inches)	Total height of tree - feet					
	40		60		80	
	Percent of stem length utilized in logging					
	50	70	50	70	50	70
	Volume remaining - cubic feet					
6	.9	.3	1.3	.4	—	—
8	1.6	.5	2.3	.7	3.1	.9
10	2.4	.7	3.6	1.1	4.8	1.5
12	3.5	1.1	5.2	1.6	7.0	2.1
14	4.8	1.4	7.1	2.2	9.5	2.9
16	6.2	1.9	9.3	2.8	12.4	3.8
18	7.8	2.4	11.8	3.6	15.7	4.8

1/ Bark comprises 13 percent of the rough volume of aspen, Technical Note No. 362, Lake States Forest Experiment Station.

2/ Values for jack pine are about 5 percent higher than values shown.

3/ Based on Tables 3 and 9 in "Composite Volume Tables and Their Application in the Lake States," unpublished manuscript, Lake States Forest Experiement Station.

Wood Chips for Agricultural Uses

Numerous uses in agriculture have been reported for wood chips that can be produced with a portable chipper from unmerchantable wood material around the farm.

The U. S. Soil Conservation Service reports that wood chips have been used successfully in the improvement of impoverished soils and the maintenance of humus content (7). Other investigators (1) (6) have found that wood chips are satisfactory mulching material for orchard trees and other horticultural crops (figs. 6 and 7). Wood chips also have been found to remain loose, dry, and clean when used as poultry litter (7). More recent tests in Indiana (2) have found that wood chips exhibit many desirable qualities for cattle bedding.

Sufficient wood material for chips exists on most farms. Limbs pruned from orchard trees can be disposed of with a portable chipper and the chips can be scattered around the trees for mulch, thereby solving two problems in one operation. Other sources of wood material for chips are logging slash or poor quality trees in the farm woods.

Fuel

Wood chips are bing used to some extent in the East for fuel. As yet this use has not been developed in the Lake States region.

Disposal Purposes

Slash Disposal

The machine was not tested specifically for slash disposal, but experiments with portable chippers elsewhere suggest that chipping is more expensive than burning and is justifiable only where burning is impracticable, as in areas of high fire hazard (3) or high aesthetic value (fig. 8).

Disposal of Roadside and Right-of-Way Brush

Portable wood chippers have already proven to be useful, money-saving tools in the disposal of brush and tree trimmings which ordinarily are piled and burned, or hauled away, dumped, and burned, as along right-of-ways. Brush can be piled somewhat faster than it can be fed. to a chipper. However, if the piled brush has to be burned, considerable added cost is entailed. Brush usually cannot be burned where cut along right-of-ways. For example, it is usually not permissible to burn brush under utility lines because the heat generated may damage the wires above. In many cases the brush to be piled and burned must be carried considerable distances, an operation that increases the costs of piling and burning. Under these circumstances, chipping is usually less expensive because the brush may be chipped where it is cut and the chips, in most instances, can be scattered along the right-of-way (fig. 9).

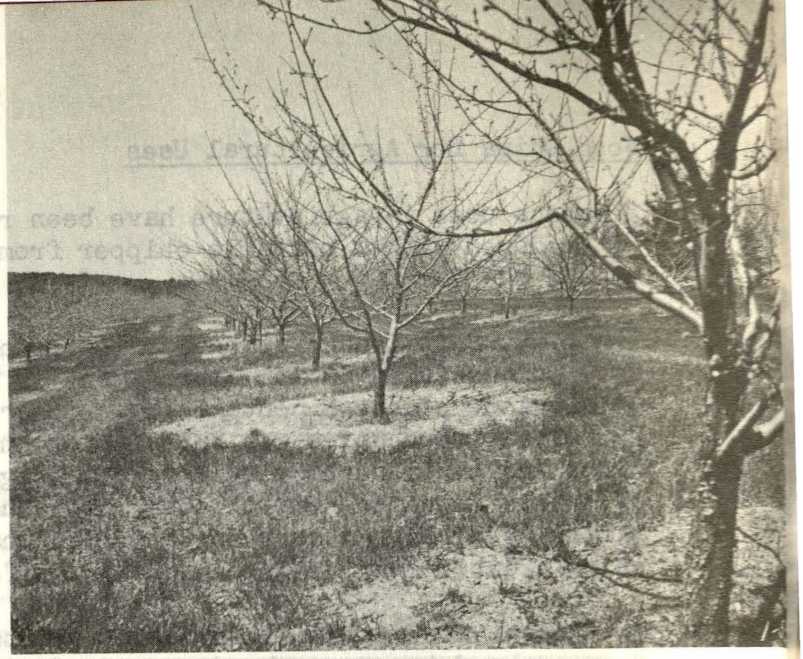
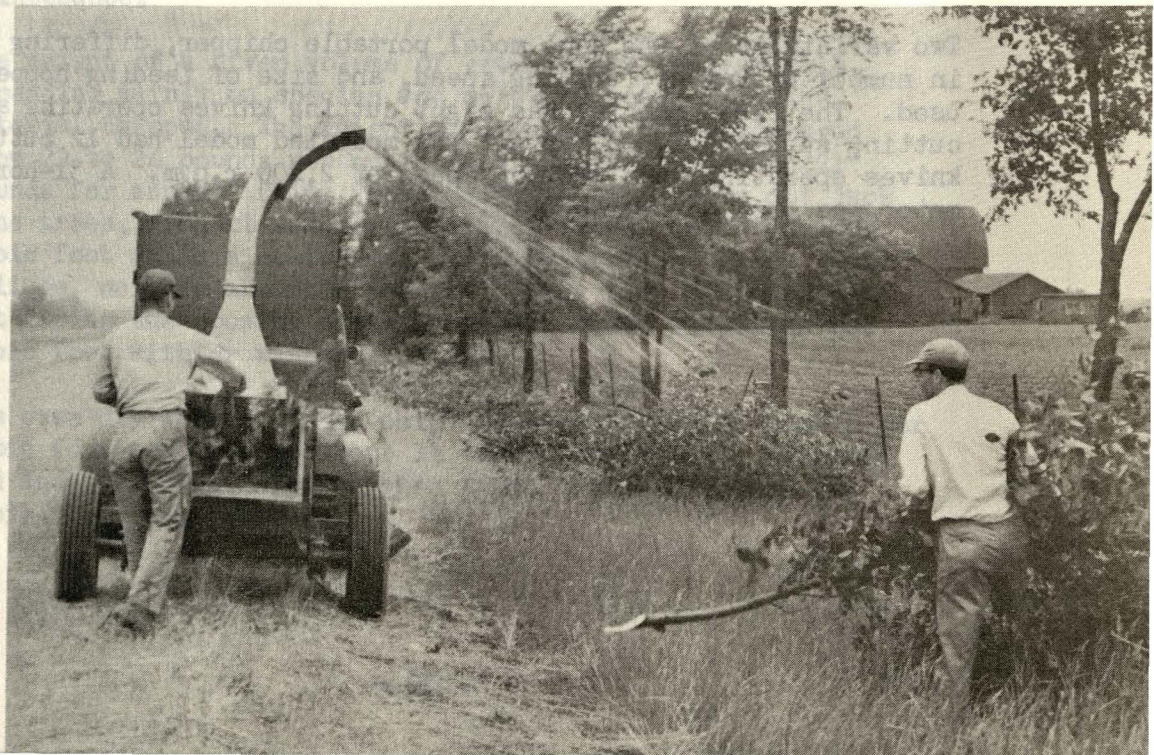


Figure 6.—Orchard prunings may be chipped and spread on the ground beneath the trees to form an effective mulch. (Photo by USDA, Soil Conservation Service.)

Figure 7.—Wood chips from woodlot operations applied as a mulch on raspberries. (Photo by USDA, Soil Conservation Service.)

Figure 8.—A portable wood chipper being used to dispose of coniferous slash along a road to reduce fire hazard. Normally the chips would be blown on the ground; they were caught in this case for measurement purposes.

Figure 9.--Portable wood chippers are money-saving tools for disposing of brush and tree trimmings where the material would otherwise have to be piled and hauled away for disposal.



More significant savings may be realized where the brush must be hauled away and dumped. On many operations the wood chips can be scattered where the brush is cut and the costly process of loading, hauling, and dumping can be eliminated. Where the material must be hauled away and dumped, chips will make fewer loads than loose brush. For example, it was found that an average of 15 cubic feet of carefully piled brush would reduce to only 1 cubic foot of chips (figs. 2a and 2b).

SUMMARY

Several makes of portable chippers that produce wood chips from material of smaller size than is merchantable on commercial logging operations are currently on the market. These portable chippers have been used extensively for the disposal of small brush where handling costs are quite high. Their uses for forestry purposes, however, have not been fully explored. To investigate the possibilities of portable wood chippers in the field of forest management, a cooperative study, consisting of a series of performance tests utilizing logging residue from pulpwood operations as well as roadside brush, was made in Lower Michigan during 1953.

Chipping performance tests were made, using oak, aspen, and pine wood, to determine production rates, operational costs, general adaptability and portability of the chipper for slash and brush disposal and utilization operations. The wood material was separated by random lengths into three general top diameter classes---0 to 1 inch, 1 to 4 inch, and 4 to 6 inch.

Two variations of the same model portable chipper, differing mainly in number of knives, cutting speed, and size of feeding hopper were used. The first machine had eight cutting knives operating at a cutting speed of 1,500 r.p.m. The modified model had 12 cutting knives operating at a cutting speed of 2,200 r.p.m. A 31-horsepower motor was used on both models.

Significant findings of the study are as follows:

1. The portable chipper tested was found to be well balanced and highly mobile for woodland, roadside, and right-of-way operations.

2. Although the chipper tested can be operated by one man, it was found that two men are the most efficient size crew on most operations.

3. Wood chip production rates with the 8-knife machine varied from 77 cubic feet of chips per hour from oak limbs, less than 1 inch in diameter, to 241 cubic feet of chips per hour from aspen wood 4 to 6 inches in diameter. With this machine, chip production rates increased with the diameter of the wood material chipped, except for small jack pine limbs.

4. Wood chip production rates with the faster cutting 12-knife machine varied from 128 cubic feet per hour for oak 4 to 6 inches in diameter to 286 cubic feet per hour for small oak brush. With this machine chip production rates decreased as the diameter of the wood material increased, except for aspen.

5. Both machines had ample power for chipping wood material up to 4 inches in diameter. When wood material 4 to 6 inches in diameter was chipped continually, the 12-knife chipper used was underpowered.

6. Costs averaged about $1.53 per hour for machine operation and maintenance.

7. The weight of a given volume of green chips was variable, depending mainly on species and moisture content of the material chipped. The weight of green oak chips averaged from 22 to 24 pounds per cubic foot compared to 17 to 21 pounds for aspen. Chips from the stems of freshly cut jack pine trees, without needles, averaged nearly 30 pounds per cubic foot while a cubic foot of chips from the limbs, with foliage, weighed about 18 pounds. Chips from red pine wood, cut during the growing season, weighed about 21 pounds per cubic foot with or without foliage.

8. The oven-dry weight of oak chips averaged about 15 pounds per cubic foot compared to about 11 pounds for aspen. Oven-dry red and jack pine chips weighed about 9 and 10 pounds per cubic foot, respectively.

9. It was found that volume of green chips in a truck decreased between 2 and 4 percent due to compaction from shaking during 1 to 4 miles of hauling.

10. The wood chips produced with this portable chipper from material 1 to 6 inches in diameter were small in size, ranging from about 1/2 inch in width, 1/4 inch in length, and 1/16 inch in thickness to fine material the equivalent of sawdust. Chips from small brush less than 1 inch in diameter were coarse and irregular in texture and size.

11. The ratio of wood chip volume to solid wood volume varied from about 2.3:1 for oak and jack pine to about 2.5:1 for aspen. According to these ratios, 1 standard cord of wood will produce about 200 cubic feet of chips.

12. The ratio of piled brush volume to volume of wood chips varied from 13:1 to 20:1 for both oak and aspen, with an average of 15:1.

13: Portable wood chippers are in current use on roadside and right-of-way slash disposal operations where the brush and tree trimmings otherwise would have to be piled and burned or hauled away. They may also be used for general slash disposal on logging operations in special areas of high fire hazard, or in recreational areas for aesthetic purposes where slash burning is impracticable.

14. Chips produced from rough wood by portable wood chippers of the type tested are not generally used by the pulp and paper industry mainly because of small size and lack of uniformity of the chips, high proportion of bark and leaves, mixture of species, and uncertainty of supply. If these objectionable features can be minimized, the low production costs relative to standard pulpwood should make it possible to market chips from sticks 1 to 4 inches in diameter that are currently being left in the woods on most pulpwood operations.

15. Portable wood chippers are a useful tool on certain farm operations for the disposal of orchard trimmings and as a tool for producing chips for livestock bedding, poultry litter, and mulch from available nonmerchantable trees and other wood material in the farm woods.

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